A Rotamak EUV Source

Masami Ohnishi, Waheed Hugrass[1], Yukio Miyake, Tatsuya Shimizu, Hodaka Osawa, Kazuya Hanatani, tatsuya Hada

Kansai university, Osaka, Japan

[1]University of Tasmania, Launceston, Tasmania, Australia

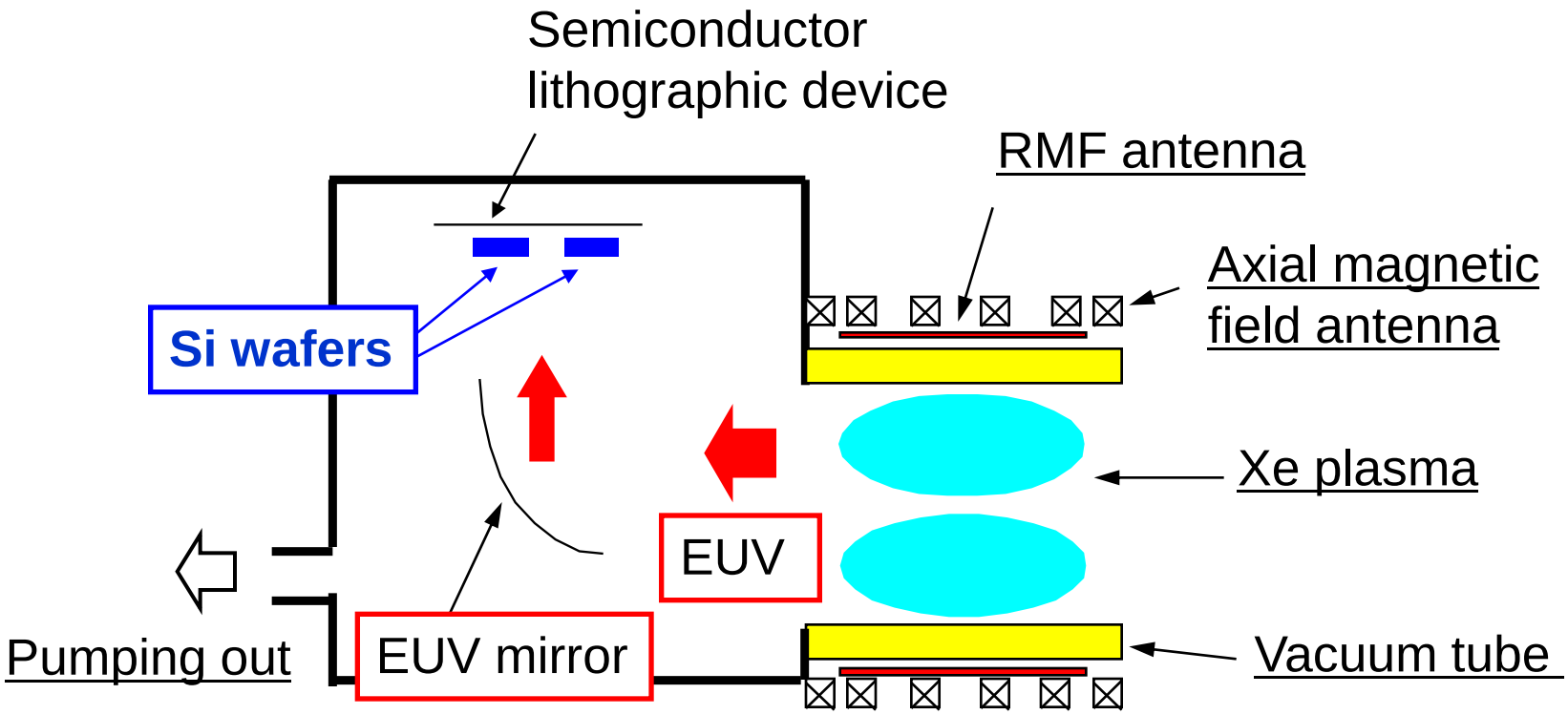
Purposes of the Study

Two approaches to produce EUV for the lithographic application are studied.

1. Rotamak Plasma
2. Microwave Plasma

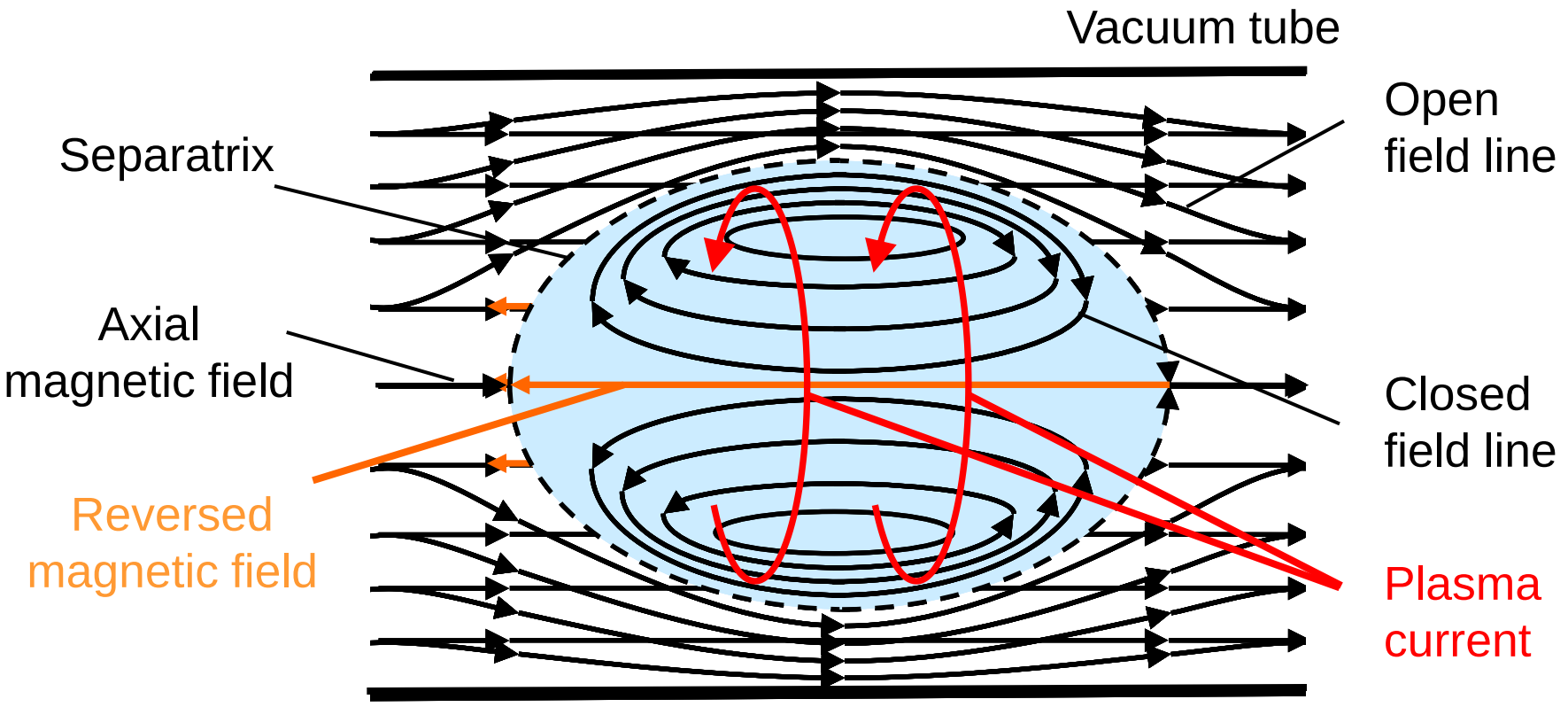
- Both of the plasma are produced by the electrodeless discharge.
- No problems of “debris” are arisen.

Conceptual Design of Semiconductor Lithography by Rotamak Plasma

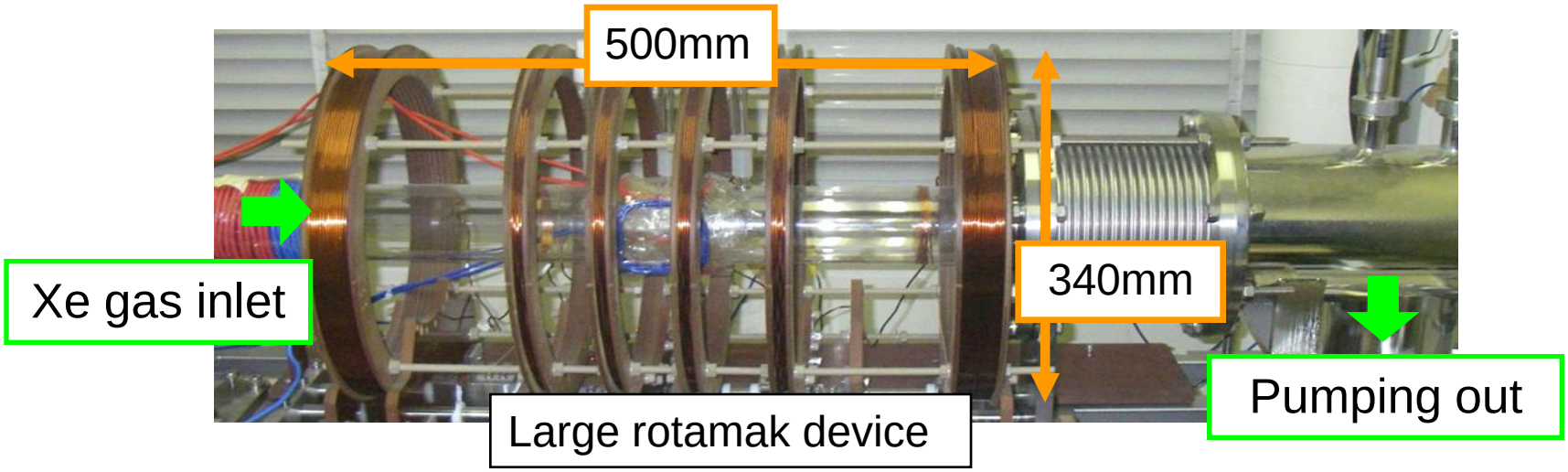


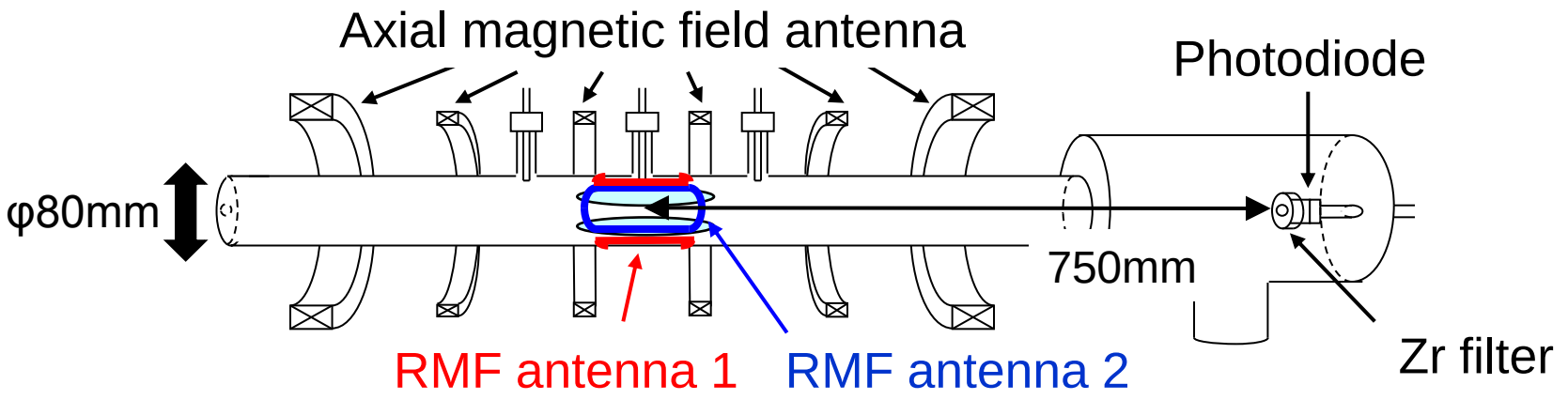
What is Rotamak？

The device has been studied for developing a fusion reactor more than 20 years.



Rotamak Experimental Device



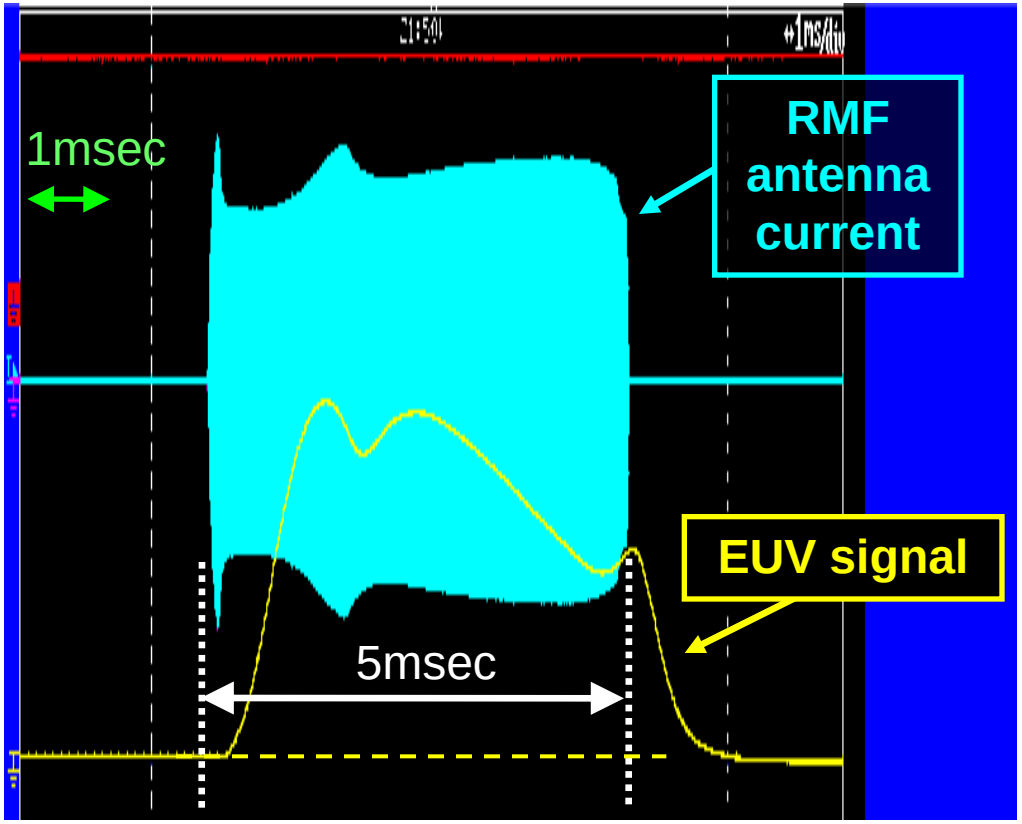


RMF Antenna Current and EUV Signal

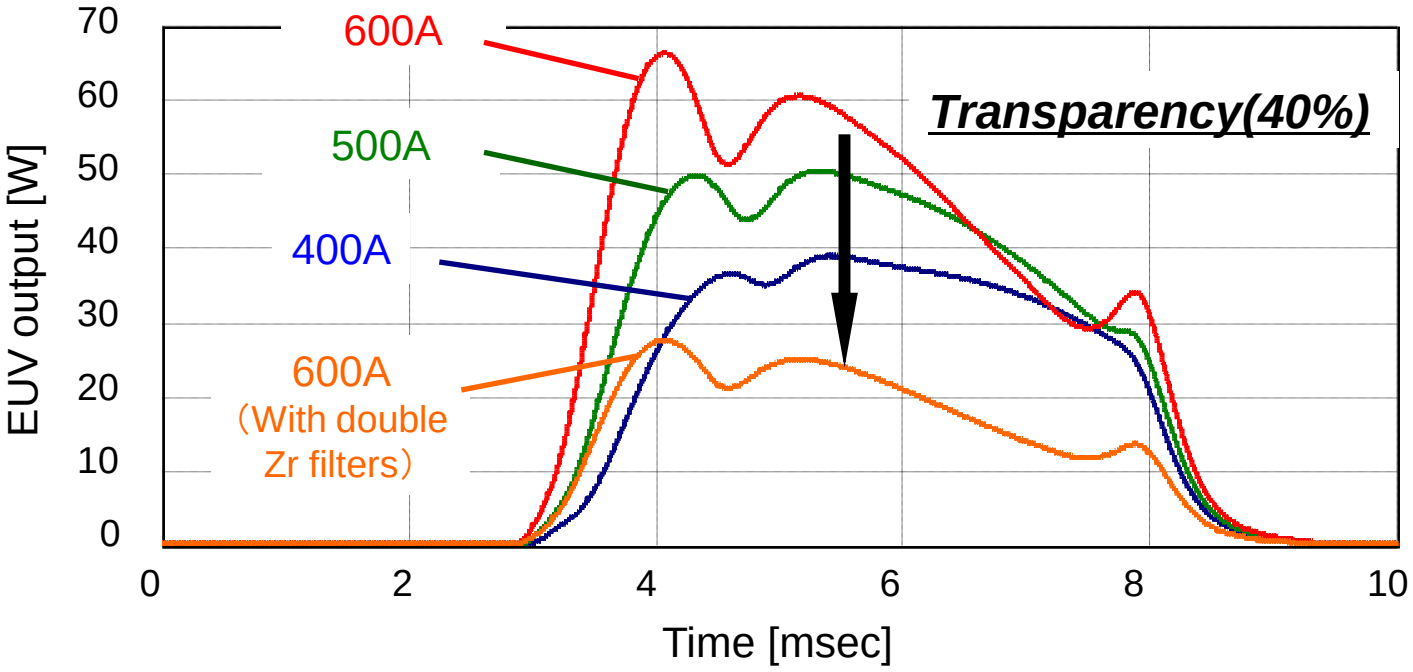
$$I_{RMF} = 400 \sim 600A$$

＜Experimental conditions＞

Period of externally applied axial magnetic field	800msec
Period of RMF current	5msec
RMF current	400~600A
Frequency of RMF	200kHz
Gas	Xe
Gas pressure	7Pa



Evaluation of EUV Output Power



Calculation of EUV power

$$S_a \cong \frac{P_{EUV}}{V_o} \cong \frac{4\pi R^2}{A_d} \times \frac{P_d}{V_o} \times \frac{1}{0.4} = \frac{4\pi (750)^2}{20} \times \frac{1}{13.3\times10^{-3} \times 1.0\times10^{6}} \times \frac{1}{0.4} = 66.5W/V$$

Distance between plasma and photodiode

Sensitivity area

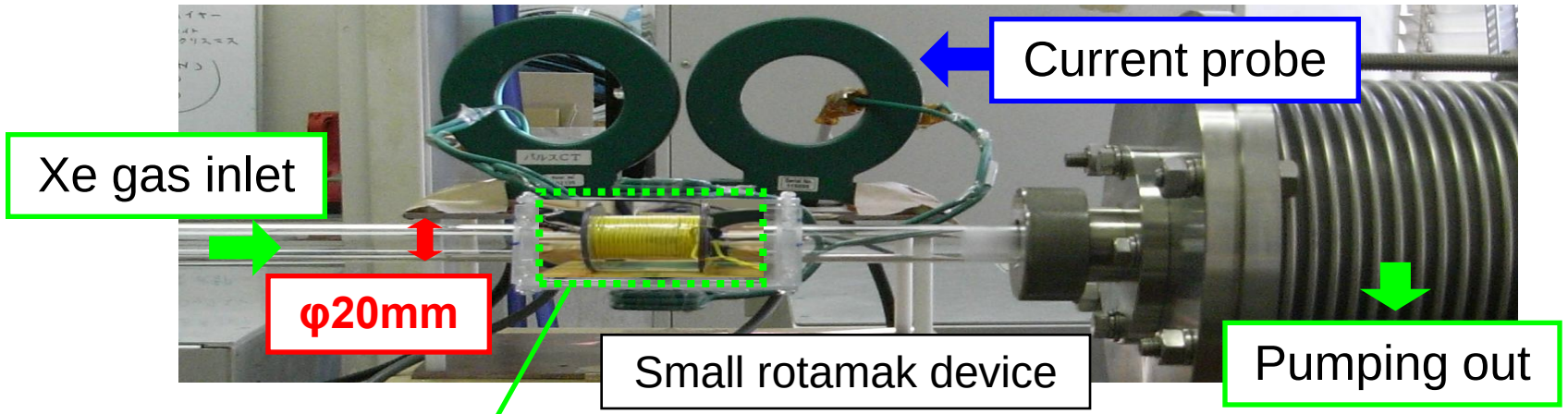
Quantum efficiency

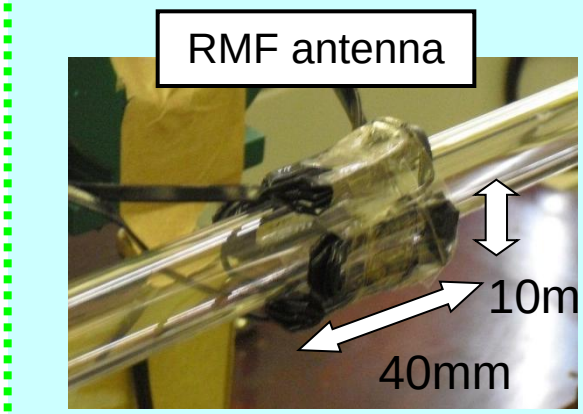
Transparency

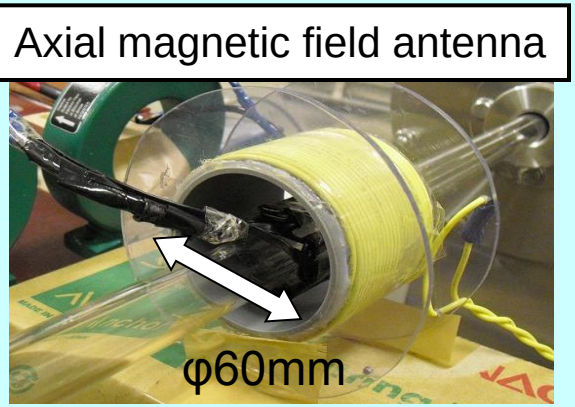
Resistivity of amplifier

Small Rotamak Device

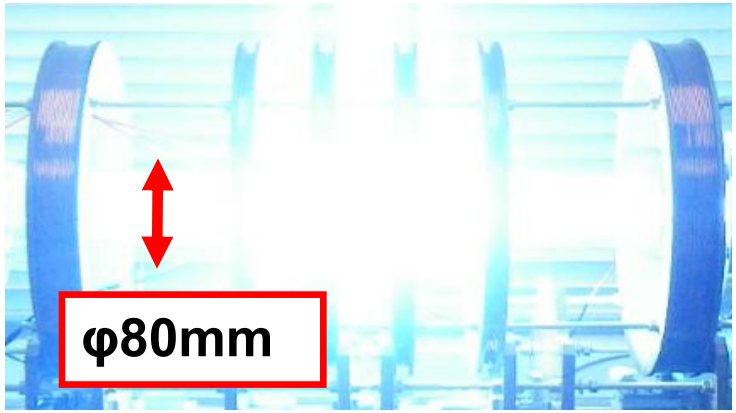
Vacuum tube;φ80mm→φ20mm



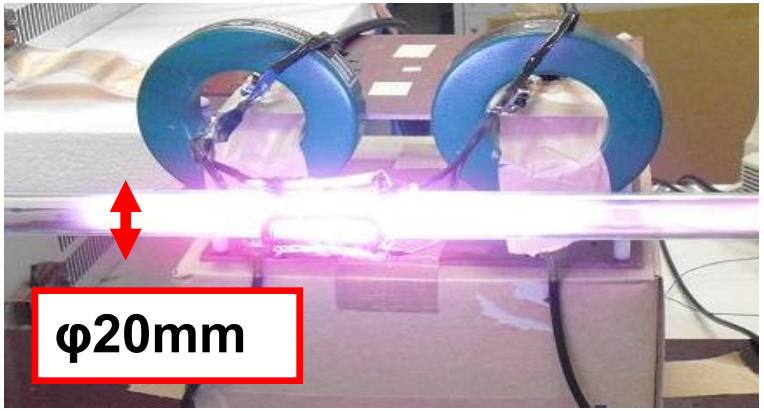




Comparison of Discharge Between Large and Small Rotamaks



Large rotamak



Small rotamak

	Large rotamak	Small rotamak
Diameter of vacuum tube	80mm	20mm
Frequency	200kHz	13.56MHz
Input power	80kW	3kW

No EUV in small rotamak has been confirmed yet.

Production of EUV by Using Microwave Plasma

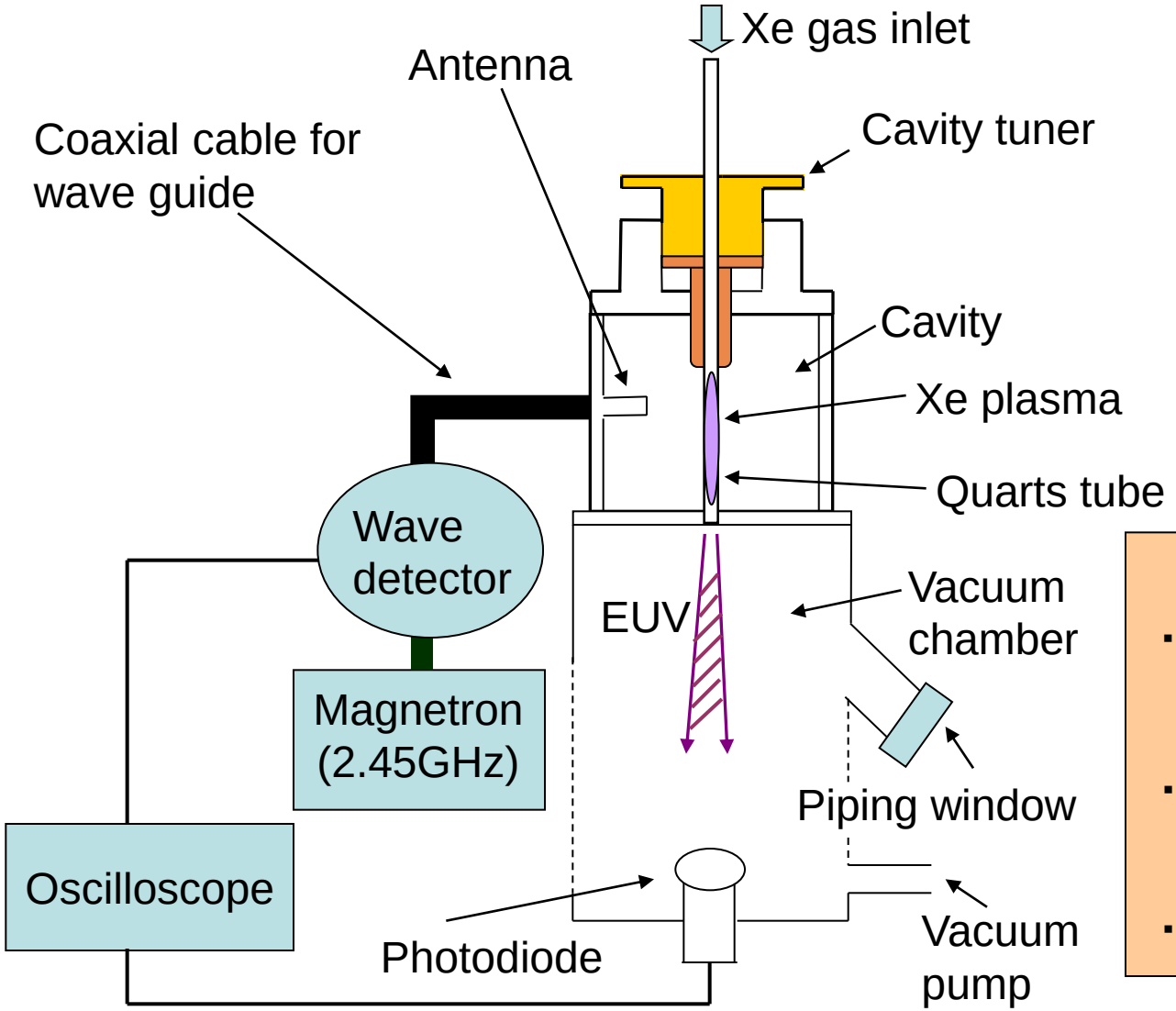
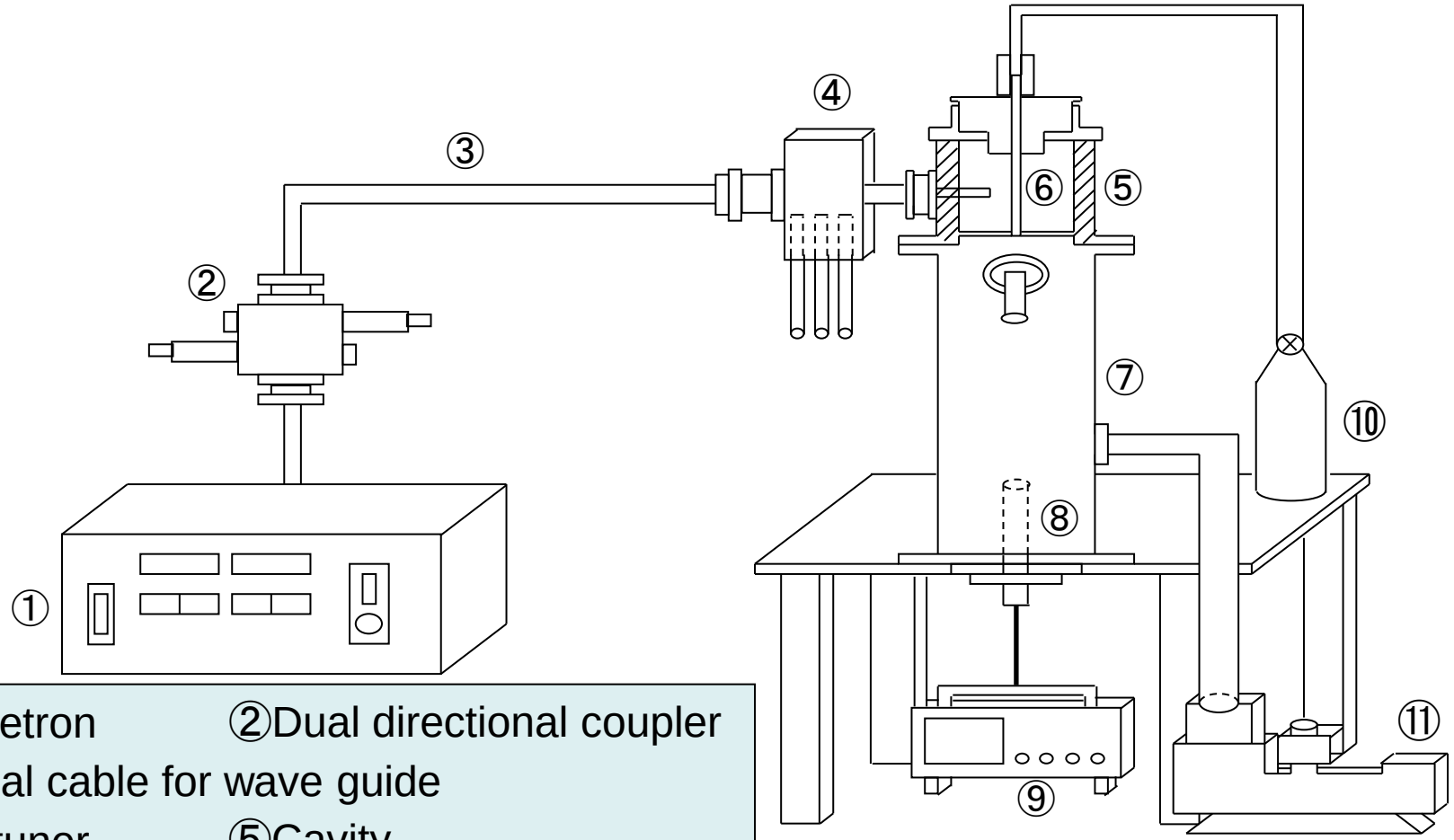


Photo of plasma

- Advantage -

- Electrodeless plasma production
- Pulse plasma formation (～1kHz)
- Small size

Diagram of Experimental Facility



①Magnetron ②Dual directional coupler
③Coaxial cable for wave guide
④Stab tuner ⑤Cavity
⑥Quarts tube ⑦Vacuum chamber
⑧Photodiode measuring EUV
⑨Oscilloscope ⑩Xe gas cylinder
⑪ Rotary pump

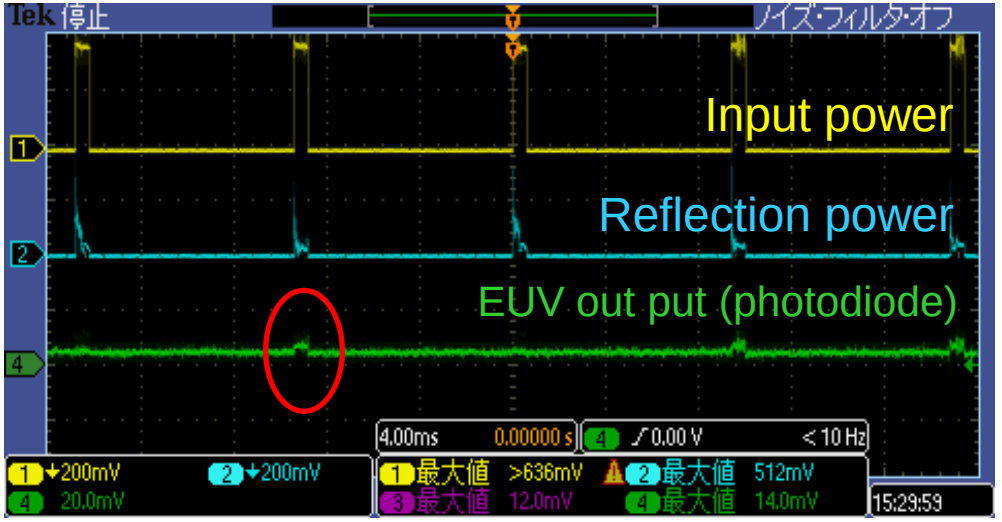
Measurement of EUV Power

＜Experimental conditions＞

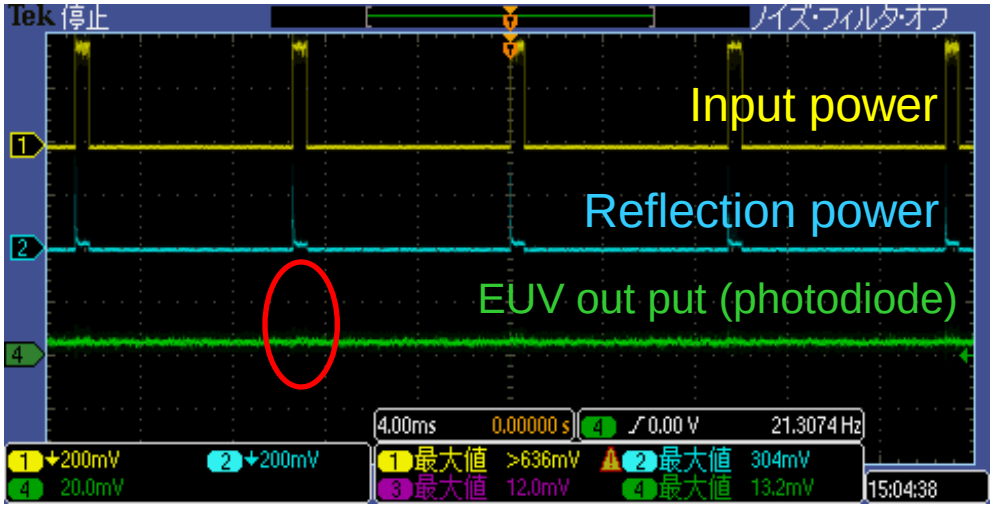
Gas	Xe
Gas pressure	7Pa
Input of microwave	400W
Microwave frequency	2.45GHz
Duty ratio	10%
Repetition frequency	100Hz

The Q-value of the cavity is achieved to be 2,500 for TM010 mode.

- 1W EUV power is obtained
- No EUV signal is observed in putting the grass on the photodiode



(a) EUV out put signal



(b) With grass

Summary and Conclusions

＜Rotamak plasma＞

- Large rotamak produces EUV more than 60W.
- The efforts are concentrated in making rotamak so smaller as to satisfy the lithographic light source conditions.

＜Microwave plasma＞

- The microwave plasma produces 1W EUV by 2.45 GHz magnetron with 400W.
- More EUV output would be expected by optimizing the plasma condition and increasing the magnetron power.